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Ambient Air Audits of Analytical Proficiency 1982

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The report summarizes results of the Ambient Air Audits of Analytical Proficiency for the calendar year 1982. Audits were conducted for SO_2, NO_2, sulfate, nitrate, lead, carbon monoxide and hi-vol flow rate. The National Performance Audit Program is also described.

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AMBIENT AIR AUDITS OF ANALYTICAL PROFICIENCY
-1982-

by

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ABSTRACT

This report presents the results of the U.S. Environmental Protection Agency's 1982 National Audit Program by pollutant and by analytical method. Semiannual audits were conducted for SO_2 and NO_2 (bubbler methods), Pb, NO_3^- and $SO_4^=$ (filter strips) and CO (continuous monitors). One audit was conducted on high-volume flow rate. Continuous SO_2 monitors were audited throughout the year, such that no monitor was audited more than once. Fifty-one laboratories participated in the 0482 SO_2 bubbler audit and 36 in the 1082 audit, and 35 in each NO_2 bubbler audit. Approximately 60 laboratories participated in each $SO_4^=$ audit, 50 in each NO_3^- audit and 100 in each Pb audit. Approximately 400 CO monitors were checked in each CO audit and 153 continuous SO_2 monitors were checked throughout the year. A total of 1496 flow devices were audited. Approximately 6 percent of the overall results were rejected as statistical outliers, a value consistent with that observed in previous audits.

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SECTION 1

INTRODUCTION

The 1982 ambient air audits of analytical proficiency, which were managed by the Environmental Monitoring Systems Laboratory (EMSL), of the U.S. Environmental Protection Agency (EPA), are a part of a continuing audit program of six ambient air pollutants and high-volume samplers. The program, entitled the National Performance Audit Program, allows EPA to monitor the performance of laboratories making air pollution measurements and participating agencies to assess their performance with respect to other agencies. The audits are conducted by the Quality Assurance Division (QAD) of EMSL, Research Triangle Park, North Carolina. Inquiries and applications to participate should be directed to this address.

Agencies participating in the audits are solicited by the EPA Regional Quality Control Coordinator in each of EPA's 10 regions. Once a laboratory enrolls in a particular audit, it is automatically notified of subsequent audits of that pollutant. Participants are assigned a permanent identifying code number. Federal, state, local, industrial and foreign air pollution monitoring agencies participate in the surveys.

Sample materials furnished for the audits are designed to simulate the several types of collected air pollution samples as closely as possible. The materials for the manual methods primarily evaluate only the analytical portion of the total air measurement process; i.e., they do not determine errors in sample collection, transportation, handling, storage, and data processing.

Audits are presently conducted twice a year for carbon monoxide, sulfur dioxide, nitrogen dioxide, lead, sulfate and nitrate and once a year for high-volume flow rate. Audits on SO_2 continuous monitors are conducted throughout the year. At the end of the year, a comprehensive report is prepared summarizing the audit results of that year. Each participant is sent a copy of their audit results.

In addition, each laboratory participating in an audit receives an evaluation of its performance shortly after the audit is completed. Laboratories submitting abnormally high or low results are offered an opportunity to analyze another set of samples. However, the retest results are not included in the summary report.

This report presents the results of EPA's ambient air audits for 1982. Approximately 300 laboratories participated in the program. The category and number of participants in each audit are presented in Table 1. This table shows that the number of agencies participating in the 1982 SO_2 an

NO_2 bubbler method audits decreased 30 to 40 percent from the number participating in the 1981 audits. The increase in the number of CO and SO_2 (continuous) monitors was insignificant as was the number of participants in the flow rate and SO_4 audits. There was a 10% increase in participation in the August audit of NO_3 over the previous year.

Throughout this report, reference is made to "assigned values." These values are the standards against which reported results are gauged and have been so designated after consideration of the analytical results of the referee laboratory, the QAD/EMSL Standards Laboratory, and the manufacturer of the audit material.

SECTION 2

SUMMARY AND CONCLUSIONS

The 1982 results are consistent with those of recent years when mid-range sample results are compared. After removal of outliers, the percentage of results within 20 percent of the assigned values ranged from 78.1 percent for the SO_2 bubbler to 100 percent for CO. The overall average for all audits is 95.4 percent which is an improvement over the 90.3 average over the past four years.[1,2] This is the first time in four years that the overall average has increased. In the previous four years the overall average was essentially unchanged.

The following percentage of results were rejected as outliers for each type of audit: SO_2 bubbler (8%), NO_2 bubbler (4.3%), CO (2.3%), $SO_4^=$ (5.4%), NO_3^- (8.0%), Pb (6.0%), and flow rate (8.5%).

SECTION 3

AUDIT MATERIALS

The audit samples span the wide range of pollutant concentrations experienced in ambient air monitoring. This is achieved directly with the CO samples, which are prepared in cylinders. Dilution is necessary for the lyophilized SO_2 and aqueous NO_2 samples in order to obtain desired concentrations. Lead, NO_3^- and $SO_4^=$ filter strip samples require both dissolution and dilution to arrive at the needed range of concentrations. The SO_2 continuous monitor audit samples require dilution of the SO_2 with zero air.

Although many air monitoring sites rarely encounter pollutant concentrations at the higher audit sample levels, they are included to assure that monitoring methods are verified at the higher levels.

The following paragraphs describe each sample type used in the 1982 audits.

SULFUR DIOXIDE (MANUAL)

Lyophilized samples, composed of sodium sulfite and potassium tetrachloromercurate, simulate ambient air samples collected according to the Pararosaniline Method, the reference method for determining SO_2 in the atmosphere. In the 1982 audits, the concentrations ranged from approximately 40 to 265 µg of sulfur dioxide equivalent per cubic meter when reconstituted properly. A sample set consisted of five different concentrations.

NITROGEN DIOXIDE (MANUAL)

Nitrogen dioxide samples consist of aqueous sodium nitrite solutions that simulate ambient NO_2 samples collected by a 24-hour NO_2 bubbler method. Audit results are expressed in terms of micrograms per milliliter (nitrite concentration). These solutions, when properly diluted according to directions, are equivalent to collected atmospheric NO_2 concentrations of approximately 6 to 20 $\mu g/m^3$. A sample set consists of five different concentrations.

CARBON MONOXIDE

These audit materials consist of a mixture of CO, CO_2 and CH_4 and zero air in a pressurized gas cylinder that simulates an ambient air sample. The concentrations of the three CO samples used in the 1982 audits ranged from 5 to 44 ppm. Directions specify that the gas sample be intro-

duced into a continuous analyzer in the "sample" mode, which permits the analyzer to draw the sample in the same fashion and at the same flow rate as during ambient air monitoring.

SULFATE, NITRATE AND LEAD ON FILTER STRIPS

The filter strip samples used in sulfate, nitrate and lead audits are each 1.9 cm wide by 20 cm long. They are cut from 20- by 24-centimeter glass fiber filters that have been spiked with an aqueous solution of the appropriate solution and then oven dried. After analysis, pollutant concentrations are computed by assuming that the samples were collected on the prescribed high-volume filter with a sample air volume of 2,000 m^3. Six sample strips comprise a set.

Sulfate and nitrate audit samples are prepared from sodium sulfate and potassium nitrate. Calculated nitrate concentrations ranged from 0.54 to 15 $\mu g/m^3$ and sulfate from 1.4 to 29 $\mu g/m^3$. Lead samples, which are prepared from lead nitrate ranged in concentration from 0.3 to 11 $\mu g/m^3$ of lead.

HIGH-VOLUME FLOW RATE (ReF DEVICE)

The reference flow (ReF) device used for audits of high-volume flow rates consist of a modified orifice, a wind deflector, a manometer, and a series of resistance plates that simulate particulate loading. A single ReF device is supplied to each participating agency with instructions to check samplers at as many sampling sites as feasible within the allotted time.

Each ReF device is calibrated with a positive displacement meter before use. During use, the device is mounted on top of the sampler, replacing the filter face plate. A wind deflector is used to prevent fluctuations in the measurements due to wind blowing across the orifice.

SULFUR DIOXIDE CONTINUOUS MONITORS

Introduced in 1981, the continuous monitor auditing system is an auditing device for SO_2 continuous ambient air monitors. The device is a porous plug dilution system that provides a mechanism whereby controlled quantities of SO_2 and diluent air are continuously combined in a mixing chamber and passed into the monitor. The flow rate of each gas is controlled by maintaining a predetermined pressure drop across the porous plus flow restrictor. Variable SO_2 concentrations are obtained by switching between four restrictors.

The audit device, which is housed in a compact, lightweight, impact-resistant case, is constructed so that only those controls required for system operation are exposed. By opening and closing different toggle valves, it is possible to generate up to seven preset pollutant concentrations. Five are used for the audit. Two compressed gas cylinders are supplied with each unit, one as the pollutant source and the other for dilution.

Each audit device is calibrated for flow at all the settings used in the audit. Flow calibrations are referenced to laminar flow elements traceable to National Bureau of Standards flow standards. Sulfur dioxide concentrations ranging from 0.00 to 0.755 ppm were used in the 1982 audits.

SECTION 4

AUDIT RESULTS

The results of the 1982 audit are presented in Tables 2 through 22. The term "audit mean" in these tables denotes the average of all values reported by the participants for that sample after correcting for outliers. Rejection of results as outliers was based on Chauvenet's Criterion.[3] The percent accuracy (% Acc.) and the precision, as measured by the percent coefficient of variation (% CV), were computed as follows:

$$\% \text{ Acc.} = \frac{\text{audit median} - \text{EPA assigned value}}{\text{EPA assigned value}} \times 100\%$$

$$\% \text{ CV} = \frac{\text{audit standard deviation}}{\text{audit mean}} \times 100\%$$

SULFUR DIOXIDE

There were 51 laboratories participating in the April (0482) and 36 in the October (1082) audit. The results, with outliers deleted, were used to calculate the mean, percent accuracy, and percent CV values reported in Tables 2 and 3. The corrected data were also used to compute the data in Table 4, which shows the percentage of laboratories that obtained results within $\pm$ 10, 20, 30, and 50 percent of the assigned values.

The negative bias of previous years' audits appears only in the 0482 audit. In the 1082 audit the reported values exceed the assigned values (Table 2). Lower average accuracy and precision is apparent in the lower sample concentrations in both audits.

As shown in Table 3, accuracy ranged from -4.9 to 3.4 percent for the manual pararosaniline method and from -14.6 to 10.2 percent for the automated method. Contrary to the previous year, precision by the manual and automated methods did not show improvement with increased sample concentration. Also, the participants in 1982 used the pararosaniline method exclusively.

As shown in Table 4, with one exception, 80 percent or more of the

laboratories reported results within ± 20 percent of the assigned values. This is an improvement over the audits of the previous year.

NITROGEN DIOXIDE

Approximately 35 laboratories took part in each of the two surveys. With outlier values deleted, the audit mean, percent accuracy, and percent CV values are given in Tables 5 and 6. The percentage of laboratories that achieved results within ± 10, 20, 30, and 50 percent of the assigned values is tabulated in Table 7.

Only minor differences between the overall audit averages and the assigned values were observed. The results of the first audit (0682) showed a slight positive bias; 1082 audit showed a slight negative bias. The differences, which ranged from 0.001 to 0.020 μg NO_2/mL, are in accord with those seen in the 1981 survey.

Overall accuracy, which ranged from 0.0 to 1.6 percent, was a definite improvement over the 1981 audits (-1.7 to 2.3). Considerable improvement was also noted in the overall precision of the 1982 audits when compared to the 1981 audits.

As shown in Table 7, 100 percent of the laboratories were within ± 20 percent of the assigned values and with two exceptions were within ± 10 percent. The 1982 audits were quite an improvement over the 1981 audits when only 95 percent of the laboratories were within this range.

CARBON MONOXIDE

Approximately 400 monitors were checked in each audit. The actual number of participants was lower, however, because many of them checked more than one instrument. The audit mean, percent accuracy, and percent CV values are presented in Tables 8 and 9. Table 10 shows the percentage of measurements within ± 10, 20, 30, and 50 percent of the assigned values.

There were considerable differences between the average results for the NDIR and GC methods. For example, accuracy ranged from -2.7 to 0.8 percent in the two audits by the NDIR method and -12.1 to 0.7 percent by the GC method. Because similar results were obtained in audits conducted the previous two years, it is reasonable to conclude that the NDIR method is more accurate in the concentration ranges employed. With the exception of one level, the precision using the GC method also showed improvement over the previous year's audits. A few of the participants used other methods such as gas filter correlation and electrochemical.

One can see in Table 10 that more than 97 percent of the monitors gave results within ± 20 percent of the assigned values, a percentage slightly larger than the previous year. The level of performance has been relatively stable in recent years,[1] indicating that further significant improvements are not to be expected.

SULFATE ON FILTER STRIPS

Sixty-four laboratories participated in each audit. The audit mean, percent accuracy, and percent CV values are tabulated in Tables 11, 12, and 13; and the percentage of laboratories having results within ± 10, 20, 30, and 50 percent of the assigned values is shown in Table 14. These results have been corrected for outliers.

In general the manual methods indicate that precision and accuracy improved as the sample concentrations increased. In the automated methods only the Methyl Thymol Blue 0282 audit follows this pattern. With one exception the lowest concentration level has the worst precision and accuracy. This applies to all four methods used.

As shown in Table 14, except for the lowest sample concentration, between 82 and 100 percent of the laboratories reported results within ± 20 percent of the assigned values. This indicates that performance has improved significantly over the 1981 audits.

NITRATE ON FILTER STRIPS

Approximately 50 laboratories participated in each of the audits. The audit mean, percent accuracy, and percent CV values appear in Tables 15 and 16; the percentage of laboratories having results within ± 10, 20, 30, and 50 percent of the assigned values is presented in Table 17. The results have been corrected for outliers. Only results by the automated methods are tabulated because of the relatively few manual methods results reported.

Results of the ion chromatograph (IC) method showed definite improvement in both precision and accuracy over the results of the previous year. Overall the IC method yielded better results than the cadmium reduction method.

Other methods used by a few participants were the manual cadmium reduction, brucine, ultraviolet spectrophotometry, hydrazine, and 2,4 xylenol methods. The number of results reported, however, was too small to calculate precision and accuracy estimates.

As shown in Table 17, excluding the lowest sample concentration, from 90 to 100 percent of the results were within ± 20 percent of the assigned values. This improvement over the 1981 audits is similar to that shown in the sulfate audits.

LEAD ON FILTER STRIPS

Approximately 100 laboratories participated in each lead audit. The audit mean, percent accuracy, and percent CV values are shown in Table 18. The percentage of laboratories producing results within ± 10, 20, 30, and 50 percent of the assigned values is indicated in Table 19. These results have been corrected for outliers.

Good accuracy prevailed in both the 0182 and 0782 audits, although both showed a slightly negative bias. The precision improved over the previous year's study in 9 of 12 samples, suggesting that, with respect to precision, the analytical method is largely unaffected by concenration over the range used in the audit. Two of the laboratories used the inductively coupled argon plasma optical emission spectrometric method; all others used the atomic absorption method.

As shown in Table 19, aside from one low concentration sample, 94 percent or more of the results were within $\pm$ 20 percent of the assigned values. Results from the 1980 and 1981 audits show a similar level of accuracy.[1]

SULFUR DIOXIDE (CONTINUOUS MONITORS)

Monitors are replacing the bubbler method for SO_2 because: (1) they offer real-time, continuous values; (2) they are easier to operate; and (3) they are more accurate at the low levels of SO_2 now in the ambient air. Most state and local agencies now use SO_2 monitors. For this reason, a device was developed that could audit continuous SO_2 analyzers at concentrations within the normal ambient SO_2 concentration range (0-1 ppm). It was introduced into the National Audit Program in 1981.

Seventy-one laboratories used the device in 1982 to check 153 monitors (Table 20). The three most commonly audited types of analyzers were fluorescence (110), flame photometric (27), and coulometric (10). The accuracy achieved by each type of monitor is presented in Table 21.

Over a similar range of assigned values, there was a dramatic improvement in the mean percent difference of the 1982 reported values compared to the 1981 with the most outstanding improvement occurring in the flame photometric analyzers.

HIGH-VOLUME FLOW RATE

One hundred ninety-two agencies participated in this program with an average participation of 7.8 sites per agency. The pressure transducer/continuous recorder was the most frequently used measurement method (42.8%), followed by the rotameter (33%), pressure transducer/flow controller (2.9%), and the flow controller (1.9%) methods. The remaining methods were mainly orifice manometer, manometer, flow gauge and pressure transducer/noncontinuous methods. These other devices represented 19.4 percent of the results. The results are summarized in Table 22. A result within $\pm$ 4.5 percent of the EPA assigned value was considered to be within the "sample range,"[1] the highest level of proficiency. For example, Table 22 shows that, overall, 30 percent of the flow meters achieved an accuracy within 1.59 percent of the assigned value and 50 percent achieved an accuracy within 3.81 percent.

TABLE 1. AGENCY PARTICIPATION

Survey	Distribution (%)					No. of Laboratories	No. of Monitors
	States	Local	Industry	Federal	Foreign		
SO_2 -- April 1982	23.6	41.2	31.4	2.0	2.0	51	NA
SO_2 -- October 1982	22.2	36.1	38.9	2.8	0.0	36	NA
NO_2 -- June 1982	35.1	56.8	8.1	0.0	0.0	37	NA
NO_2 -- December 1982	27.3	54.5	18.2	0.0	0.0	33	NA
CO -- March 1982	36.9	42.0	14.0	5.1	1.9	NA	409
CO -- September 1982	38.2	42.7	12.1	4.5	2.5	NA	384
SO_4 -- February 1982	43.8	25.0	23.4	3.1	4.7	64	NA
SO_4 -- August 1982	45.3	25.0	20.3	3.1	6.2	64	NA
NO_3 -- February 1982	42.9	24.5	24.5	2.0	6.1	49	NA
NO_3 -- August 1982	46.2	23.1	21.2	1.9	7.7	52	NA
Pb -- January 1982	42.4	23.2	30.3	2.0	2.0	99	NA
Pb -- July 1982	45.0	25.0	26.0	2.0	2.0	100	NA
SO_2 (continuous)	40.5	28.8	30.1	0.7	0.0	NA	153
High-Volume Flow-Rate -- May 1982	33.0	44.0	19.5	6.0	0.5	NA	1496

NA = Not applicable

TABLE 2. AUDIT RESULTS FOR SULFUR DIOXIDE

Audit	Level	n*	Assigned value ($\mu g/m^3$)	Mean ($\mu g/m^3$)	% Acc.	% CV
0482	1	46	37.20	36.33	-1.6	15.1
	2	45	64.40	62.26	-3.7	11.1
	3	44	118.40	112.25	-5.7	9.4
	4	45	173.20	171.65	1.3	9.5
	5	45	198.60	192.74	1.0	9.5
1082	1	34	187.30	191.18	3.4	11.1
	2	33	93.70	96.50	3.5	13.2
	3	33	41.30	42.39	6.4	18.5
	4	32	200.30	201.96	-0.2	7.4
	5	32	265.70	268.59	0.7	6.6

*Survey 0482: Data returned by 51 participants (n).
*Survey 1082: Data returned by 36 participants (n).

TABLE 3. RESULTS FOR THE PARAROSANILINE METHOD

Audit	Level	Assigned value ($\mu g/m^3$)	Manual method				Automated method			
			n	Mean ($\mu g/m^3$)	% Acc.	% CV	n	Mean ($\mu g/m^3$)	% Acc.	% CV
0482	1	37.20	40	36.16	-1.4	27.6	9	32.84	- 9.1	12.5
	2	64.40	39	61.67	-2.2	17.8	9	55.32	-14.6	10.5
	3	118.40	39	111.40	-4.9	15.8	9	101.11	-11.3	10.1
	4	173.20	40	170.50	1.6	13.8	10	156.71	- 6.8	16.3
	5	198.60	40	190.36	-0.9	14.2	10	181.17	- 8.3	13.2
1082	1	187.30	24	188.15	0.2	9.8	11	199.87	7.7	21.3
	2	93.70	23	95.56	0.5	10.0	11	102.85	10.2	21.8
	3	41.30	24	40.15	3.4	22.7	11	47.16	9.8	19.8
	4	200.30	24	198.02	-1.4	6.0	11	206.08	4.6	20.4
	5	265.70	24	264.26	-1.9	6.4	11	271.47	4.7	21.9

TABLE 4. PERCENT OF SULFUR DIOXIDE MEASUREMENTS WITHIN INDICATED PERCENT OF ASSIGNED VALUES

Audit	Level	Assigned value ($\mu g/m^3$)	10%	20%	30%	50%
0482	1	37.20	54.3	80.4	95.7	100.0
	2	64.40	60.9	93.5	100.0	100.0
	3	118.40	62.2	91.1	97.8	100.0
	4	173.20	71.7	93.5	95.7	97.8
	5	198.60	78.3	91.3	97.8	100.0
1082	1	187.30	69.7	90.9	100.0	100.0
	2	93.70	57.6	84.8	97.0	100.0
	3	41.30	51.5	66.7	90.9	97.0
	4	200.30	87.5	96.9	100.0	100.0
	5	265.70	84.4	100.0	100.0	100.0

TABLE 5. AUDIT RESULTS FOR NITROGEN DIOXIDE

Audit	Level	n*	Assigned value (µg/ml)	Mean (µg/ml)	% Acc.	% CV
0682	1	32	0.339	0.343	1.6	4.3
	2	33	0.588	0.590	0.7	3.6
	3	32	0.737	0.740	1.0	3.2
	4	33	0.930	0.937	1.4	3.0
	5	32	1.127	1.128	0.0	3.2
1282	1	32	0.400	0.397	-0.8	3.7
	2	32	0.551	0.542	-0.9	2.8
	3	32	0.650	0.643	-1.0	2.8
	4	32	0.851	0.835	-1.3	2.4
	5	32	1.101	1.081	-1.2	2.9

*Audit 0682: Data returned by 37 laboratories.
*Audit 1282: Data returned by 33 laboratories.

TABLE 6. AUDIT RESULTS FOR NITROGEN DIOXIDE BY THE SODIUM ARSENITE METHOD

Audit	Level	Assigned value (µg/mL)	Manual method				Automated method			
			n	Mean (µg/mL)	% Acc.	% CV	n	Mean (µg/mL)	% Acc.	% CV
0682	1	0.339	22	0.343	1.9	15.1	7	0.344	1.8	2.0
	2	0.588	22	0.590	1.1	15.0	8	0.597	1.2	2.0
	3	0.737	21	0.742	1.6	15.1	8	0.746	1.4	1.7
	4	0.930	22	0.939	1.7	14.9	8	0.937	1.4	2.0
	5	1.127	21	1.128	-0.3	15.3	5	1.125	0.3	2.7
1282	1	0.400	21	0.398	-0.2	2.0	8	0.401	-1.0	4.7
	2	0.551	21	0.543	-1.1	2.6	8	0.543	-1.6	2.3
	3	0.650	20	0.642	-1.0	1.7	8	0.642	-1.8	2.9
	4	0.851	20	0.840	-1.3	1.2	9	0.821	-3.4	4.8
	5	1.101	21	1.082	-1.5	2.0	9	1.071	-0.6	5.2

TABLE 7. PERCENTAGE OF NITROGEN DIOXIDE MEASUREMENTS WITHIN INDICATED PERCENTAGE OF ASSIGNED VALUE

Audit	Level	Assigned value (µg/mL)	10%	20%	30%	50%
0682	1	0.34	100.0	100.0	100.0	100.0
	2	0.59	100.0	100.0	100.0	100.0
	3	0.74	100.0	100.0	100.0	100.0
	4	0.93	100.0	100.0	100.0	100.0
	5	1.13	96.9	100.0	100.0	100.0
1282	1	0.40	93.8	100.0	100.0	100.0
	2	0.55	100.0	100.0	100.0	100.0
	3	0.65	100.0	100.0	100.0	100.0
	4	0.85	100.0	100.0	100.0	100.0
	5	1.10	100.0	100.0	100.0	100.0

TABLE 8. AUDIT RESULTS FOR CARBON MONOXIDE

Audit	Level	n*	Assigned value (ppm)	Mean (ppm)	% Acc.	% CV
0382	1	389	5.55	5.34	-2.7	7.6
	2	393	19.20	19.26	0.5	3.4
	3	383	35.10	34.96	-0.3	2.7
0982	1	377	9.88	9.86	0.2	5.0
	2	374	26.40	26.59	0.4	3.4
	3	369	43.90	43.99	0.0	3.0

*Audit 0382: Data returned for 409 monitors.
Audit 0982: Data returned for 384 monitors.

TABLE 9. AUDIT RESULTS FOR CARBON MONOXIDE BY THE NDIR AND GC METHODS

Audit	Level	Assigned value (ppm)	NDIR				GC			
			n	Mean (ppm)	% Acc.	% CV	n	Mean (ppm)	% Acc.	% CV
0382	1	5.55	382	5.34	-2.7	8.0	5	4.78	-12.1	7.40
	2	19.20	387	19.30	0.5	4.2	5	18.25	- 5.2	1.92
	3	35.10	381	35.02	-0.3	3.7	5	34.3	- 1.4	2.80
0982	1	9.88	352	9.88	0.2	5.0	5	9.02	- 5.9	7.42
	2	26.40	348	26.64	0.8	3.4	5	25.62	- 2.3	2.6
	3	43.90	343	44.08	0.2	3.0	5	44.00	0.7	1.3

TABLE 10. PERCENTAGE OF CARBON MONOXIDE MEASUREMENTS WITHIN INDICATED PERCENTAGE OF ASSIGNED VALUE

Audit	Level	Assigned value (ppm)	10%	20%	30%	50%
0382	1	5.55	83.2	97.0	99.5	100.0
	2	19.20	96.2	99.5	100.0	100.0
	3	35.10	96.9	100.0	100.0	100.0
0982	1	9.88	92.6	100.0	100.0	100.0
	2	26.40	97.6	100.0	100.0	100.0
	3	43.90	98.6	100.0	100.0	100.0

TABLE 11. AUDIT RESULTS FOR SULFATE ON FILTERS STRIPS

Audit	Level	n*	Assigned value ($\mu g/m^3$)	Mean ($\mu g/m^3$)	% Acc.	% CV
0282	1	57	1.44	1.91	4.2	47.2
	2	57	6.96	6.95	1.7	14.8
	3	56	12.36	12.38	-0.8	9.1
	4	56	18.00	18.05	1.0	7.9
	5	57	23.42	23.44	-0.1	6.6
	6	58	28.80	28.56	-0.5	7.3
0882	1	55	1.32	1.58	4.5	40.1
	2	58	6.36	6.34	-0.9	11.2
	3	59	11.28	11.27	-1.4	9.9
	4	61	16.32	16.27	0.2	5.7
	5	61	21.36	21.55	0.0	8.1
	6	59	26.40	26.10	-0.8	6.3

*Audit 0282: Data returned by 64 laboratories.
Audit 0882: Data returned by 64 laboratories.

TABLE 12. AUDIT RESULTS FOR SULFATE BY THE MANUAL METHODS

Audit	Level	Assigned value (µg/m³)	$BaCl_2$				Sulfa-Ver			
			n	Mean (µg/m³)	% Acc.	% CV	n	Mean (µg/m³)	% Acc.	% CV
0282	1	1.44	11	2.47	47.2	55.6	6	2.91	104.9	26.6
	2	6.96	11	7.22	2.0	18.5	6	7.18	5.2	13.1
	3	12.36	11	12.59	2.9	9.8	6	12.90	5.0	10.8
	4	18.00	11	18.37	2.2	9.1	6	18.49	0.8	10.8
	5	23.42	11	23.71	1.2	5.5	6	23.53	2.9	7.5
	6	28.80	11	28.83	0.3	8.0	6	28.76	1.0	5.0
0882	1	1.32	12	1.95	27.3	35.7	5	2.97	43.9	69.0
	2	6.36	13	5.94	-6.0	21.5	6	7.31	15.6	9.7
	3	11.28	12	11.79	2.1	15.9	6	11.48	-2.6	11.5
	4	16.32	13	16.55	2.2	7.3	7	16.30	1.1	7.6
	5	21.36	13	22.02	1.1	7.4	7	20.44	-3.1	10.2
	6	26.40	13	26.75	0.8	10.6	6	24.98	-7.4	6.5

TABLE 13. AUDIT RESULTS FOR SULFATE BY THE AUTOMATED METHODS

Audit	Level	Assigned value ($\mu g/m^3$)	Methyl Thymol Blue				Ion Chromatograph			
			n	Mean ($\mu g/m^3$)	% Acc.	% CV	n	Mean ($\mu g/m^3$)	% Acc.	% CV
0282	1	1.44	22	1.61	3.8	37.0	16	1.48	0.0	13.1
	2	6.96	22	6.78	-1.9	10.2	14	6.68	-3.2	6.2
	3	12.36	22	12.34	-1.4	9.1	14	12.00	-1.2	4.7
	4	18.00	21	17.97	1.2	6.8	15	17.84	0.5	6.0
	5	23.42	21	22.97	-1.0	5.3	16	23.53	1.7	7.2
	6	28.80	23	28.18	-1.0	7.6	15	29.18	2.7	6.6
0882	1	1.32	25	1.36	2.3	25.0	14	1.31	-5.7	32.9
	2	6.36	25	6.29	-0.9	10.2	14	6.04	-5.1	5.2
	3	11.28	26	11.07	-1.3	7.3	14	11.03	-2.3	3.1
	4	16.32	26	16.05	-0.6	5.3	14	16.28	0.5	2.5
	5	21.36	26	21.48	-1.8	9.2	14	21.61	0.9	3.8
	6	26.40	26	25.93	-2.9	6.1	14	26.76	1.3	4.5

TABLE 14. PERCENTAGE OF SULFATE MEASUREMENTS WITHIN INDICATED PERCENTAGE OF ASSIGNED VALUES

Audit	Level	Assigned value ($\mu g/m^3$)	10%	20%	30%	50%
0282	1	1.44	47.4	56.1	63.2	75.4
	2	6.96	66.7	82.5	94.7	98.2
	3	12.36	73.2	94.6	100.0	100.0
	4	18.00	80.4	100.0	100.0	100.0
	5	23.42	86.0	98.2	100.0	100.0
	6	28.80	82.8	100.0	100.0	100.0
0882	1	1.32	40.0	58.2	63.6	85.5
	2	6.36	69.0	91.4	100.0	100.0
	3	11.28	78.0	94.9	98.3	100.0
	4	16.32	91.8	100.0	100.0	100.0
	5	21.36	83.6	95.1	100.0	100.0
	6	26.40	93.2	100.0	100.0	100.0

TABLE 15. AUDIT RESULTS FOR NITRATE ON FILTERS STRIPS

Audit	Level	n*	Assigned value ($\mu g/m^3$)	Mean ($\mu g/m^3$)	% Acc.	% CV
0282	1	39	0.72	0.81	2.8	30.0
	2	41	3.60	3.70	2.2	9.4
	3	42	6.42	6.57	0.5	10.9
	4	44	9.30	9.37	0.6	8.9
	5	44	12.12	12.20	1.2	9.2
	6	44	15.00	14.91	0.8	9.1
0882	1	46	0.54	0.67	6.5	40.1
	2	46	3.24	3.24	-1.4	9.5
	3	46	6.00	5.97	-0.2	6.6
	4	47	8.70	8.69	-0.8	6.3
	5	48	11.40	11.31	-0.9	4.9
	6	47	14.10	13.87	0.1	6.4

*Audit 0282: Data returned by 49 laboratories.
Audit 0882: Data returned by 52 laboratories.

TABLE 16. AUDIT RESULTS FOR NITRATE BY THE AUTOMATED METHODS

Audit	Level	Assigned value ($\mu g/m^3$)	Ion Chromatograph				Cadmium Reduction			
			n	Mean ($\mu g/m^3$)	% Acc.	% CV	n	Mean ($\mu g/m^3$)	% Acc.	% CV
0282	1	0.72	15	0.66	-2.7	19.2	16	1.09	8.3	59.0
	2	3.60	14	3.60	1.1	5.1	17	4.12	2.2	39.0
	3	6.42	15	6.31	-0.3	8.6	17	7.32	3.6	33.7
	4	9.30	15	9.33	-0.2	7.7	17	10.54	1.4	34.1
	5	12.12	16	12.13	0.7	9.2	17	14.47	2.7	41.6
	6	15.00	15	14.91	1.0	7.4	17	16.75	1.7	28.8
0882	1	0.54	14	0.58	0.0	39.8	22	0.69	11.1	53.3
	2	3.24	13	3.14	-1.2	9.7	21	3.10	-0.6	25.5
	3	6.00	13	5.89	-1.3	9.0	21	5.85	-1.7	17.7
	4	8.70	13	8.71	-0.3	7.7	20	8.65	-1.1	6.2
	5	11.40	13	11.38	0.0	4.6	20	11.19	-0.9	4.8
	6	14.10	13	14.10	1.3	5.2	22	12.88	-2.3	25.3

TABLE 17. PERCENTAGE OF NITRATE MEASUREMENTS WITHIN INDICATED PERCENTAGE OF ASSIGNED VALUE

Audit	Level	Assigned value ($\mu g/m^3$)	10%	20%	30%	50%
0282	1	0.72	46.2	64.1	71.8	87.2
	2	3.60	78.0	95.1	97.6	100.0
	3	6.42	73.8	90.5	97.6	100.0
	4	9.30	79.5	97.9	100.0	100.0
	5	12.12	79.5	93.2	100.0	100.0
	6	15.00	77.3	95.5	100.0	100.0
0882	1	0.54	45.7	50.0	69.6	76.1
	2	3.24	73.9	95.7	100.0	100.0
	3	6.00	93.5	97.8	100.0	100.0
	4	8.70	89.9	100.0	100.0	100.0
	5	11.40	97.9	100.0	100.0	100.0
	6	14.10	89.4	100.0	100.0	100.0

TABLE 18. AUDIT RESULTS FOR LEAD ON FILTER STRIPS

Audit	Level	n*	Assigned value ($\mu g/m^3$)	Mean ($\mu g/m^3$)	% Acc.	% CV
0182	1	90	0.32	0.32	-3.1	11.1
	2	91	1.62	1.60	-0.6	7.5
	3	92	3.60	3.52	-1.7	6.5
	4	91	5.94	5.81	-1.7	5.3
	5	88	8.28	8.17	-1.3	5.0
	6	92	10.80	10.44	-2.7	5.9
0782	1	91	0.58	0.58	0.0	11.8
	2	92	2.34	2.29	-1.3	5.7
	3	91	4.32	4.25	-1.4	4.5
	4	92	6.30	6.21	-1.1	5.6
	5	93	7.92	7.76	-1.5	5.5
	6	94	10.26	9.90	-2.0	11.5

*Audit 0182: Data returned by 99 laboratories.
Audit 0782: Data returned by 100 laboratories.

TABLE 19. PERCENTAGE OF LEAD MEASUREMENTS WITHIN INDICATED PERCENTAGE OF ASSIGNED VALUE

Audit	Level	Assigned value ($\mu g/m^3$)	10%	20%	30%	50%
0182	1	0.32	78.9	88.9	97.8	100.0
	2	1.62	81.3	97.8	100.0	100.0
	3	3.60	89.1	100.0	100.0	100.0
	4	5.94	89.0	100.0	100.0	100.0
	5	8.28	94.3	100.0	100.0	100.0
	6	10.80	87.0	98.9	100.0	100.0
0782	1	0.58	75.8	94.5	97.8	100.0
	2	2.34	91.3	98.9	100.0	100.0
	3	4.32	95.7	100.0	100.0	100.0
	4	6.30	94.6	100.0	100.0	100.0
	5	7.92	92.5	98.9	100.0	100.0
	6	10.26	89.2	97.8	100.0	100.0

TABLE 20. AUDIT RESULTS FOR SULFUR DIOXIDE CONTINUOUS MONITORS

Flow setting	Number of reported values*	Range of assigned values (ppm)	Mean differences	
			ppm	% diff
1	22	0.628 to 0.755	-0.010	-1.601
2	149	0.404 to 0.509	-0.005	-1.124
3	151	0.211 to 0.287	-0.002	-0.734
4	149	0.167 to 0.219	-0.002	-0.893
5	149	0.040 to 0.069	-0.001	-1.445
6	151	0.000	0.000	--

*1982 Audit: Data returned for 153 monitors

TABLE 21. AUDIT RESULTS FOR SULFUR DIOXIDE CONTINUOUS MONITORS BY VARIOUS INSTRUMENTAL METHODS

Flow setting	Flame photometric average difference			Fluorescent average difference			Coulometric average difference		
	n	ppm	%	n	ppm	%	n	ppm	%
1	8	-0.012	-1.8	11	-0.000	-0.2	1	---	---
2	26	-0.001	-0.2	109	-0.010	-1.3	10	-0.024	-5.5
3	27	0.003	1.3	110	-0.005	-1.2	10	-0.010	-4.4
4	27	0.001	0.8	108	-0.003	-0.9	9	-0.011	-6.0
5	27	-0.001	-1.4	109	-0.001	-1.1	10	-0.005	-8.4
6	27	0.003	---	110	0.001	---	10	0.000	---

TABLE 22. AUDIT RESULTS FOR HIGH-VOLUME FLOW RATE

Method	No. of results	Results within indicated assigned value (%)			
		30%	50%	70%	90%
Rotameter (visifloat)	1743[1]	1.50	2.97	5.23	8.88
Pressure transducer (continuous)	2221[2]	1.69	2.97	4.48	7.27
Flow controller	92[3]	1.59	3.81	5.22	6.48
Pressure transducer/flow controller	158[4]	1.85	3.08	4.48	6.02
All methods	5220[5]	1.61	3.01	4.77	7.79

[1]1945 measurements reported
[2]2524 measurements reported
[3] 114 measurements reported
[4] 173 measurements reported
[5]5900 measurements reported

REFERENCES

1. Bennett, B.I., R.L. Lampe, L.F. Porter, A.P. Hines and J.C. Puzak. National Performance Audit Program. Ambient Air Audits of Analytical Proficiency, 1981. U.S. Environmental Protection Agency Report EPA 600/4-83-009. Research Triangle Park, North Carolina 27711. April 1983.

2. Rhodes, R.C., B.I. Bennett and J.C. Puzak. EPA's National Performance Audit Program for Ambient Air Pollution Measurements. In: Proceedings of the 75th Annual Meeting of the Air Pollution Control Association, New Orleans, Louisiana, 1982. 82-23,7:1-18.

3. Chauvenet, W. A Manual of Spherical and Practical Astronomy. J.B. Lipincott and Company, Philadelphia, Pennsylvania, 1863. pp. 558-566.